

Topic 11: Gas Exchange in Humans

11.1 Features of Gas Exchange Surfaces

Gas exchange surfaces, such as the alveoli in the lungs, are highly adapted to maximize the rate of diffusion of oxygen into the blood and carbon dioxide out of the blood. The key features are:

- **Large Surface Area:** Provided by the millions of alveoli, allowing for a large volume of gas to be exchanged.
 - **Thin Surface:** The walls of the alveoli and capillaries are very thin (one cell thick), ensuring a **short diffusion distance**.
 - **Good Blood Supply:** A dense network of capillaries surrounds the alveoli, which maintains a **steep concentration gradient** for gases.
 - **Good Ventilation with Air:** The process of breathing constantly replaces the air in the alveoli, maintaining the **steep concentration gradient** for oxygen and carbon dioxide.
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Structure and Function of the Gas Exchange System

The human gas exchange system includes the following parts which you must be able to identify in diagrams and images: **lungs, diaphragm, ribs, intercostal muscles (internal and external), larynx, trachea, bronchi, bronchioles, alveoli, and associated capillaries.**

Role of Key Structures

- **Cartilage in the Trachea:** The trachea is supported by rings of cartilage. The function of this cartilage is to **prevent the trachea from collapsing** when the air pressure inside is low (e.g., during inhalation).

Mechanism of Ventilation

Ventilation (breathing) is the process of moving air into and out of the lungs. This is achieved by producing volume and pressure changes in the thorax (chest cavity).

Explain the role of the ribs, the internal and external intercostal muscles and the diaphragm in producing volume and pressure changes in the thorax leading to the ventilation of the lungs:

Process	Diaphragm	Intercostal Muscles (Ribs)	Volume of Thorax	Pressure in Lungs	Air Movement
Inhalation	Contracts (moves down and flattens).	External contract, Internal relax. Ribs Move up and out.	Increases.	Decreases (below atmospheric pressure).	Air rushes in.
Exhalation	Relaxes (moves up into a dome shape).	External relax, Internal contract . Ribs Move down and in.	Decreases.	Increases (above atmospheric pressure).	Air rushes out.

Composition of Inspired and Exhaled Air

Component	Inspired Air (Inhaled)	Expired Air (Exhaled)	Explanation
Oxygen (O ₂)	≈21%	≈16%	Oxygen diffuses from the alveoli into the blood for aerobic respiration.
Carbon Dioxide (CO ₂)	≈ 0.04%	≈4%	Carbon dioxide diffuses from the blood into the alveoli as a waste product of aerobic respiration.
Water Vapour	Variable (often low)	Saturated (high)	Air is humidified and warmed as it passes through the respiratory passages, and water is produced as a product of respiration.
Nitrogen (N ₂)	≈78%	≈78%	Nitrogen is an inert gas and is not used or produced by the body.

When expired air is bubbled through limewater, it turns cloudy (milky). Inspired air does not turn limewater **cloudy**, or does so much more slowly. This demonstrates that **expired air contains a higher concentration of carbon dioxide** than inspired air.

Effects of Physical Activity

- 1 **Increased Respiration:** During physical activity, muscle cells respire faster to release more energy.
 - 2 **Increased CO₂:** This increased respiration produces more waste **carbon dioxide**.
 - 3 **Blood CO₂ Rises:** The concentration of **CO₂** in the blood increases.
 - 4 **Detection by Brain:** This rise in **CO₂** concentration is detected by the **chemoreceptors in the brain**.
 - 5 **Increased Ventilation:** The brain sends nerve impulses to the diaphragm and intercostal muscles, leading to an **increased rate and greater depth of breathing** to quickly remove the excess **CO₂** and supply more **O₂**.
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Protection of the Breathing System

Structure	Role in Protection
Goblet Cells	Produce mucus , a sticky substance that traps dust, bacteria, and other foreign particles inhaled with the air.
Mucus	Traps inhaled pathogens and particles, preventing them from reaching the delicate gas exchange surface of the alveoli.
Ciliated Cells	Have tiny hair-like projections called cilia . These cilia beat rhythmically upwards, sweeping the layer of mucus (and the trapped particles) up the trachea and into the pharynx, where it is swallowed or coughed out. This is known as the mucus escalator .